Emotion Recognition System for Autism Children using Non-verbal Communication

R. Santhoshkumar, M. Kalaiselvi Geetha

Abstract: Human beings can express their emotions through various ways, such as facial expression, bodily expressions, prosody, or language. Autism Spectrum Disorder (ASD) is a lifelong neuro developmental disorder, characterized by varying levels of deficit in social and communications skills. This paper aims to predict basic emotions from children with autism spectrum disorder (ASD) using body movements. The facial expression is difficult for ASD children to recognize emotion. The author proposed the body movement patterns to detect the type of emotions of ASD children. In this paper 12 dimensional body movement features (angle, distance, velocity and acceleration) from head, L-hand, R-hand are proposed for predict the emotion from children body movements. The dataset for this experiment is autism children's recorded videos (5-11 years, n=10). The extracted features are given to the Support Vector Machine (SVM) and the Random Forest (RF) classifier to predict the children emotions. The performance measure can be calculated using quantitative analysis. Our finding shows that children have gradual ease in recognizing the following emotions: angry, fear, happy, sad and neutral.

Index terms: Autism Spectrum Disorder, Emotion recognition, non-verbal communication, Body movements, Body expressive feature, Support Vector Machine (SVM) and the Random Forest (RF) classifier.

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a developmental disorder that is characterized by, and diagnosed on the grounds of, social communication deficits and repetitive stereotyped behavior. Emotion recognition (ER) difficulties are considered to be common in many people with ASD and this presents a challenge, as understanding emotions helps people to act in a socially salient manner. Emotions can be identified from a variety of sources of information, including facial expressions, tone of voice and body posture. The ASD is diagnosed based on a set of behavioral criteria. These criteria include repetitive behaviors and narrow interests, as well as deficits in social behavior and delays in verbal and nonverbal communication. The characteristic behaviour in three different areas identified by Kanner and Asperger for Autistic Spectrum Disorders:

- Impairments in language
- Impairment in social interaction
- The restricted and repetitive behaviours

Firstly, children with Autistic Spectrum Disorders reveal deficits in their expressive language and impairments in communication. This could cause a whole lack of language development and leads to delay in spoken language. Secondly, the Autistic Spectrum Disorders children disrupted in understanding of others language and social inter actions. These characteristics include deficits in lacking eye-contact, facial expression, non-verbal aspects of communication and body gesture. And also leads to failure of sharing of interests with others. Social impairments may manifest as a lack of social reciprocity and insight into their own and others emotions. The restricted, repetitive and stereotyped behaviours are third type of characteristics used to diagnosis the Autistic Spectrum Disorders.

Objective of this research: This paper aims to recognize archetypical emotions of autism children (happy, angry, sad, fear, neutral) using body movements (head, center of body, L-hand, R-hand).

Motivation of this research: In the class room environment, facial view is not clear when camera is too far from autism children. This type of issue can be rectified by capturing body movements (head, hands, legs, center of body, legs) of autistic children for recognizing emotions.

Contribution of this research: The author aims to recognize emotions expressed by autistic children from body movements (head, L-hand, R-hand). The angle, distance, velocity and acceleration are features calculated from head, L-hand, R-hand points. The extracted features are given to the input of the RF and SVM classifier. Based on the emotion expressed by the autism children, the system plays the video and audio for autism children to change his mood to happy.

The flowing paper is organized as: Section I introduces the background and contribution of this paper and expression of ASD community. Related works are discussed in Section II. In Section III, describes the proposed feature and Section IV describes the performance evaluation of this experiment. Section V concludes the paper and discusses the future ideas.

II. RELATED WORKS

Alev Girli, et al.[1] developed system for children with learning disability (LD) were compared with ASD children using face and body expressions. Anthony P Atkinson, et al.[2] develop a set of discrete and continuous body expressions of basic emotions using whole body movements. Anthony P. Atkinson [3] developed the emotion recognition system for adults with ASD from point-light and

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full-light displays of body movements. Shimrit fridenson-Hayo, et al [4] develops emotion recognition system for children with autism spectrum conditions (ASC) with different expression modalities (face, voice, body). Peter G. Enticott, et al [5] describes the facial emotion recognition (FER) model deficits in autism spectrum disorder (ASD). Junkai Chen, et al [6] proposed an effective method is to handle the facial expression recognition problem. Rossana Actis-Grosso, et al [7] investigated the pictures of static faces vs. body motion contributes differently to the recognition of emotions. Tal Shafir, et al. [8] aimed to identify motor characteristics of movements whose execution enhances each of the basic emotions using Laban Movement Analysis (LMA). Ofer Golan, et al [9] describes the study reports for assessing recognition of mental states and complex emotions in social contexts. J. Grèzes, S. et al. [10] investigated how such dynamic fear signals from the whole body are perceived. Hatice Gunes, et al. [11] presents an approach to automatic visual recognition of expressive face and upper-body gestures from video sequences. Nouchine Hadjikhani, et al [12] proposed the evidence of emotion perception deficits in autism spectrum disorder (ASD) Nursuriati Jamil, et al [13] proposed the system for detect the emotions of ASD children using walking patterns. Katherine B. Martin, et al. [14] observes the motor movements in autism children.

III. PROPOSED WORK

A. Pre-processing

In this paper, the recorded video dataset are used for emotion recognition from head, L-hand, R-hand movements. The given input videos are converted into RGB frames. Background subtraction is very useful in video surveillance. As the name indicates, this algorithm works by detecting the background and subtracting it from the current frame to obtain the foreground. The foreground image is cropped by background subtractionmethod.

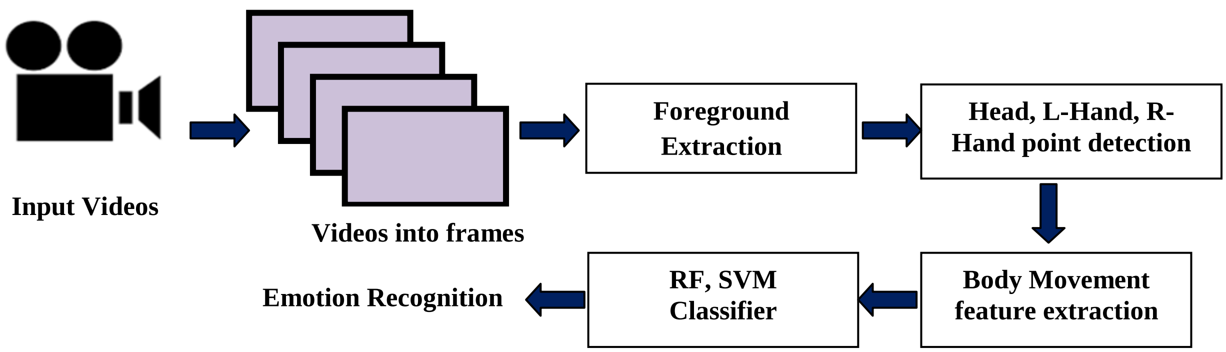

Figure 1: Architecture of proposed method

The figure 1 shows proposed block diagram and described in the following subsections.

B. Body Movement Feature (BMF)

A skin color tracking algorithm is used to extract blobs of head, L-hand and R-hand. Then the center of mass (centroid) can be calculated for three blobs. Using the center of mass, the expressive feature vectors (distance, angle, velocity, acceleration) are computed:

a) Distance of head, L-hand and R-hand with respect to body center

The hand and head movements are more useful to predict the emotions human body. The distance of hand from body center concludes the emotions of human. The Euclidean distance between head and L-hand, head and R-hand, L-hand and R-hand are considered as the three feature points. It can be calculated using distance between two points (x1, y1) and (x2, y2) with equation 1.

$$Distance = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

b) Angle between the head, L-hand and R-hand with respect to body center

The hand movements to express different emotions (happy, angry) are commonly closer to each other. An appropriate feature to distinguish these emotions is the calculation of angle between head, L-hand and R-hand. (x1, y1), (x2, y2) and (x3, y3) are the coordinates of head, L-hand and R-hand.

$$\theta = cos^{-1} \frac{a.b}{|a||b|} \quad (2)$$

Where, θ is angle, a and b are two vectors, |a| and |b| are magnitude of two vectors.

c) Average velocity of head, L-hand and R-hand

The sudden change in L-hands, R-hand and head distinguished the emotions in the human body. Therefore, the changes in position of three points are considered as important feature vector. The velocity is described as the change in position over the change in time.

$$vel_{avg} = \frac{x_{final} - x_{inital}}{t_{final} - t_{inital}} \quad (3)$$

Where, x_final and x_inital are final and initial position, t_final and t_inital are final and initial time of a single point in between successive frames. Similarly, calculate the average velocity for head, L-hand and R-hand points.

d) Acceleration of head, L-hand and R-hand with respect to body center

The hand movements in happy and anger are very fast and they are related to head movements. Therefore, the acceleration of the hands movements for happy and angry emotions is much higher than other emotions. The acceleration is calculated from the change in velocity for two successive frames.

$$Acceleration = final\_velocity \ - initial\_velocity \quad (4)$$

Therefore, totally four feature vector are calculated for each point. Finally, 12 dimensional feature vectors are computed from the head, L-hand and R-hand points in successive. The extracted feature vector is given to the random forest classifier for recognition of human emotion.

C. Random Forest (RF) Classifiers

The Random Forest (RF) algorithm is one of the supervised classification algorithms [15]. There is a direct relationship between the number of trees in the forest and the results. When increase the number of trees, the accuracy of the result can increase. The two stages of RF algorithms are creation and prediction. The creation of RF algorithm is as follows:

a. Randomly "k" features are selected from total "m" features, where k << m.
b. Calculate the node "d" from the "k" features using the best split point.
c. Split the node into daughter nodes using the best methods.
d. Steps 'a' to 'c' are repeated from until "l" number of nodes has been reached.
e. Steps 'a' to 'd' are repeated for "n" number times to create "n" number of trees.

The prediction of RF algorithm is as follows:

a. The test features taken and use the rules of every randomly created decision tree to predict and store the outcome.
b. Votes for each predicted target are calculated.
c. The high voted predicted target is considered as the final prediction from the RF algorithm.

D. Support Vector Machine (SVM) Classifier

The Support Vector Machine (SVM) is an important and efficient technique for classification in visual pattern recognition [15], [16]. The SVM is most extensively used in kernel learning algorithm. The elegant theory used to separate two classes by large-margin hyper planes. It cannot be extended easily to separate N mutually exclusive classes. The most popular "one-vs-others" approach is used for the multi class problem where, one class is separated from N classes. The classification task are typically involves with training and testing data. The training data are separated by (s_1, t_1), (s_2, t_2), ...(s_n, t_n) into two classes, where $b_j \in \{+1,-1\}$ are the class labels and $s_j \in t_N$ contains n-dimensional feature vector. The goal of Support Vector Machine is to develop a model which predicts target value from testing set. $w.s + b = 0$ is the hyper plane of binary classification, where $w \in R^N$, The two classes are separated by $b \in R$.
$M = 2/\|w\|$ is the large margin as show in Fig. 3.The Lagrange multipliers α_i (i=1, ...m) are used to solve the minimization problem, where v and y are optimal values obtained from equation 5.

$$h(s) = sgn\left(\sum_{j=1}^{n} x_j b_j L(s_j, s) + y\right) \quad (5)$$

Maximize the margin and minimize the training error using non-negative slack variables ε_j . The Eq. 13 and Eq. 14 obtain the soft margin Classifier.

$$\min_{v,y,\varepsilon} \frac{1}{2} v^R v + D \sum_{j=1}^{k} \varepsilon_j \quad (6)$$

$$b_j(v^R \emptyset(s_j)) + y \geq 1 - \varepsilon_j, \varepsilon_j \geq 0 \quad (7)$$

When the training sample is not linearly separable, the input space mapped into high dimensional space using kernel function $L(s_j s_k) = \emptyset(s_j).\ \emptyset(s_k)$.

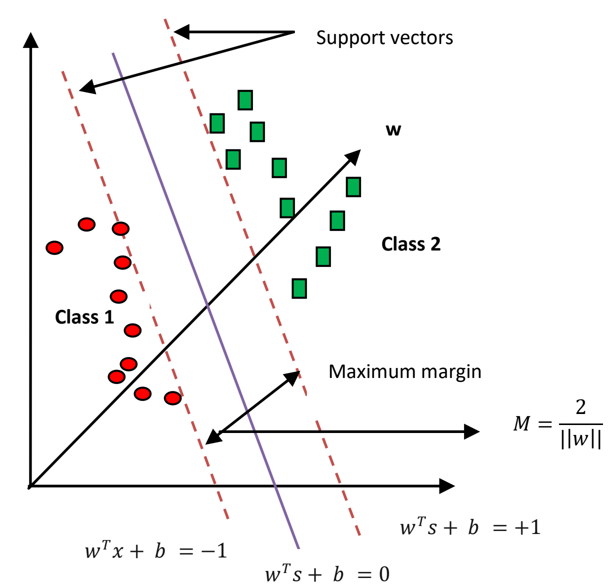

Figure 2: Illustration of hyperplane in linear SVM

Linear:

$$L(s_j s_k) = s^R j^s k \quad (8)$$

Polynomial:

$$L(s_j, s_k) = (\alpha s^R j^s k + \alpha)^c, \alpha > 0 \quad (9)$$

Radial Basis Function (RBF):

$$L(s_j, s_k) = \exp\,(-\alpha||s_j - s_k||^2), \alpha > 0 \quad (10)$$

Sigmoid:

$$L(s_j, s_k) = \tanh\,(\alpha s^R j - s_k + t) \quad (11)$$

Where, α, t, and c are parameters of kernel.

The multiclass Support Vector Machine (SVM) is constructed by N-binary classifiers and one class was separated from rest of the class. Here "one-vs-others" approach is used in this SVM. The five classes of emotions are used in this work. The j^{th} class of the training sets have positive labels and all others with negative labels. The j^{th} SVM solves j^{th} decision function given in Eq. 11. Finally, the feature vectors from the body movement feature are given into multiclass-SVM for classification of human emotion.

IV. PERFORMANCE EVALUATION METRICS

The successive five emotions are mind for predict emotion: happy, angry, sad, fear and neutral from Autistic Children Emotion (ACE) dataset. The demonstrations are conducted on Windows 10 Operating System using Anaconda Python 3. The open source Machine Learning Tool WEKA is used for recognizing the emotion with Random Forest classifier.

A. Dataset

In this research, the Autistic Children Emotion (ACE) dataset are collected from special school. The collected videos contain different emotions of autistic children. Totally 10 (boys=9, girls=1) participants are in the dataset. The resolutions of the recorded videos are 1280 × 720 and each video has 25 frames per second (fps).

B. Performance Evaluation Metrics

The confusion matrix is a table with actual classifications are columns and predicted ones are Rows.

- True Positives (TP) - when the data point of actual class and predicted was (True).
- True Negatives (TN) - when the data point of actual class and predicted was (False).
- False Positives (FP) - when the data point of actual class (False) and the predicted is (True).
- False Negatives (FN) - when the data point of actual class (True) and the predicted is (False).

	Actual class	
Predict class	TP	FP
	TN	FN

Figure 3: Confusion matrix

The performances evaluation of proposed work can be calculated using Accuracy, Recall, F-Score, Specificity and Precision. Accuracy in classification problems is the number of correct prediction made by the model over all kinds prediction made, which can be calculated using equation 12.

$$Accuracy = \frac{tp+tn}{tn+fp+tp+fn} \quad (12)$$

Recall provides how extraordinary an emotion is recognized accurately.

$$Recall = \frac{tp}{tp+fn} \quad (13)$$

The symphonies mean of Precision and Recall is called as F-score.

$$F - Score = 2\,\frac{Precision\ X\ Recall}{Precision+Recall} \quad (14)$$

Specificity shows an evaluation of how great a strategy is recognizing negative emotion accurately.

$$Specificity = \frac{tn}{tn+fp} \quad (15)$$

At last, Precision shows the proportion of classification, which can be calculated by equation (16).

$$Precision = \frac{tp}{tp+fp} \quad (16)$$

Where, tp and tn are the quantity of true positive and true negative prediction of the class and fp and fn are the quantity of false positive and false negative expectations.

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

The experiment was done using an open source Machine Learning Tool WEKA on Autistic Children Emotion (ACE) dataset. The performance of the Random Forest (RF) classifier is measured using 10-fold cross validation model. The

confusion matrix for Autistic Children Emotion (ACE) dataset is shown in Table 1.

The performances of the Random forest classifier are measured using classification true positive, false positive, Precision, Recall and F-measure values. Table 2 shows the emotions performance accuracy for Random Forest classifiers. Random forest takes more time to learn the given dataset, but also shows good accuracy rate of 94.2% for this dataset.

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Table 1. Confusion matrix of Autistic Children Emotion (ACE) for Random Forest (RF) classifier

	Angry	Fear	Happy	Neutral	Sad
Angry	78 90.7%	2 2.3%	4 4.7%	2 2.3%	0 0.0%
Fear	9 4.5%	180 90.9%	3 1.5%	4 2.0%	2 1.0%
Happy	5 4.3%	4 3.4%	107 91.5%	1 0.9%	0 0.0%
Neutral	0 0.0%	2 3.1%	4 6.3%	58 90.6%	0 0.0%
Sad	2 2.9%	5 7.2%	3 4.3%	2 2.9%	57 82.6%

Table 2. Performance Measure of Random Forest (RF) in Autistic Children Emotion (ACE) dataset

	TP Rate	FP Rate	Precession	Recall	F-Measure
Angry	90.7%	9.3%	91.7%	91.9%	92.7%
Fear	90.9%	9.1%	92.6%	90.2%	90.4%
Happy	91.5%	8.5%	91.5%	90.5%	91.1%
Neutral	90.6%	9.4%	91.4%	91.6%	90.5%
Sad	82.6%	17.4%	92.3%	89.5%	90.7%

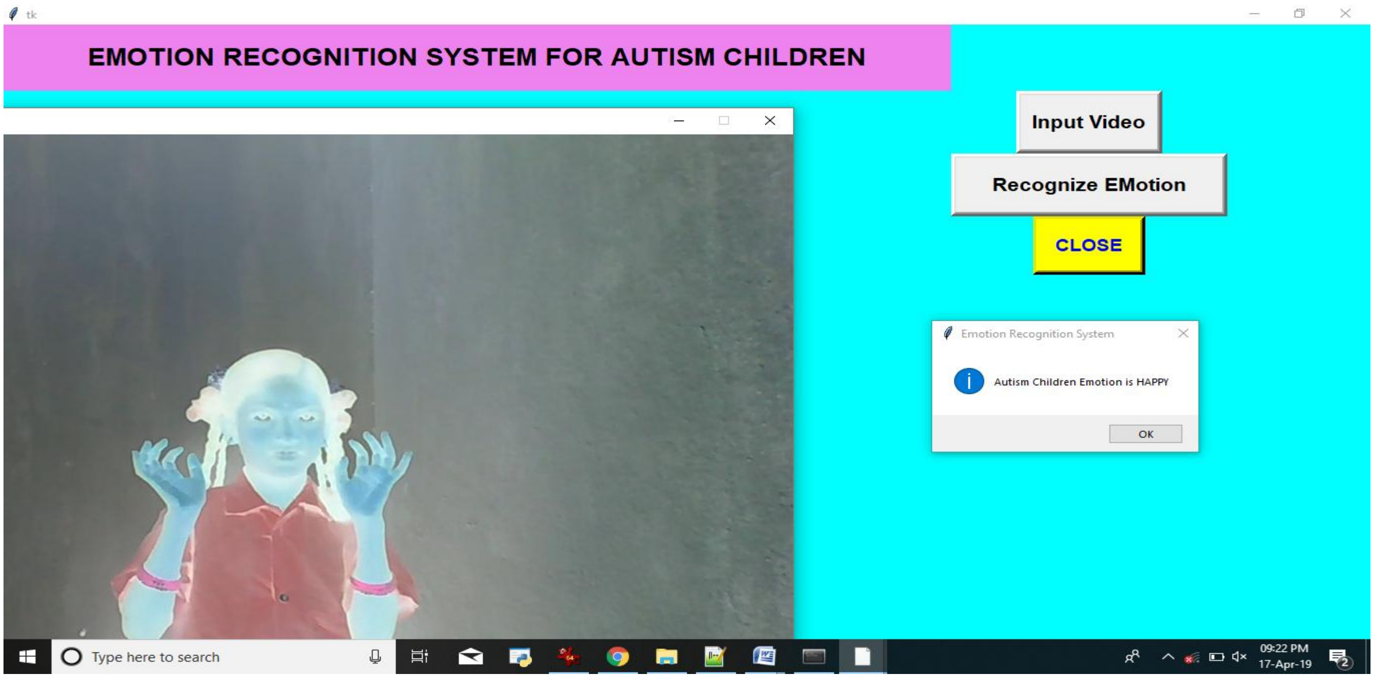

Figure 4: Recognition of Happy Emotion

Table 3. Confusion matrix of Support Vector Machine (SVM) classifier for BM feature

	Angry	Fear	Happy	Neutral	Sad
Angry	81 94.2%	4 4.7%	0 0.0%	1 1.2%	0 0.0%
Fear	2 1.0%	196 99.0%	0 0.0%	0 0.0%	0 0.0%
Happy	3 2.6%	2 1.7%	112 96.7	0 0.0%	0 0.0%
Neutral	0 0.0%	0 0.0%	0 0.0%	64 100%	0 0.0%
Sad	0 0.0%	0 0.0%	5 7.2%	0 0.0%	64 92.8

Table 4. Performance Measure of Support Vector Machine (SVM) for BM feature

	TP Rate	FP Rate	Precession	Recall	F-Measure
Angry	94.2%	5.8%	94.6%	93.2%	95.1%
Fear	99.0%	1.0%	99.3%	99.0%	99.1%
Happy	95.7%	4.3%	94.7%	94.2%	95.1%
Neutral	100%	0%	100%	100%	99.5%
Sad	92.8%	7.2%	92.5%	91.8%	93.7%

Figure 3 shows the recognition of Happy Emotion of Autism Children. Table 3 and table 4 shows the confusion matrix and performance measure of Support Vector Machine (SVM) classifier for BM feature. The performances of the SVM classifier are measured using classification true positive, false positive, Precision, Recall and F-measure values. Table 4 shows the emotions performance accuracy for SVM classifiers. SVM takes more time to learn the given dataset, but also shows good accuracy rate of 96.3% for this dataset.

VI. CONCLUSION

In this paper, proposed body movement feature for recognizing emotions of autistic children from body movements on sequence of frames. The feature points are calculated from head, L-hand, R-hand points. The proposed method is evaluated on recorded dataset having 10 autistic children. The performance of this algorithm is better than the other algorithms. Using this proposed algorithm the emotions (happy, angry, fear, sad, neutral) are recognized from autism children. Future work aims at develop research applications to recognize the emotions of adult with autism spectrum disorder (ASD).

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